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Many experienced observers indicated that stalk rot and lodging in the 2000 season were the worst they have seen in over 20 years in Iowa. These observations are difficult to verify without an objective survey, but most would agree that lodging was more severe and widespread than usual in 2000. One of the complications in assessing the situation is that lodging and stalk rot are not always equivalent. In some years, there is a lot of stalk rot with little lodging, simply because the windy weather does not come at the right time to cause the lodging. And not all lodging is due to stalk rot.

In this article I will discuss some of the factors that contribute to stalk rot and lodging, and place them in the context of the 2000 season.

Stalk Rots are Unique

Stalk rots are different from other corn diseases because they are caused by fungi that co-exist with corn plants as decomposers, but in some cases become pathogens. The populations of fungi that cause stalk rot differ from field to field but many of the same members are present in each field. *Fusarium moniliforme, Gibberella zeae*, and *Stenocarpella maydis* (*Diplodia maydis*) are among the most common causes of stalk rot and they have been found in Iowa corn for many decades. *Colletotrichum graminicola*, which causes anthracnose stalk rot, is a relative newcomer, but now must be considered among the three most common stalk rot pathogens in the state. Anthracnose became an important disease in the NC United States during the early to mid-1970's (Bergstrom and Nicholson, 1999), but in Iowa it was a bit later, during the 1980's, that the disease became common. Each of these fungi is involved in the decomposition of corn plant residue after the plants die. They can, however, infect the plants while they are alive. Their ability to do so (aggressiveness) differs among the various fungal species. All corn hybrids have some level of genetic resistance to infection by these fungi, but as the plants near natural senescence, their resistance declines and they are vulnerable to fungal attack before they reach their normal stage of maturity. Environmental factors influence whether plants will become prematurely vulnerable to stalk rot infections. Under ideal growing conditions, stalks are not infected until they are at or beyond physiological maturity. But eventually, every stalk is infected, because these are the same fungi that will decompose the stalks and return them to the soil.

Another unique aspect of stalk rots is the interaction between environmental conditions, the corn plant, and the stalk rot fungi. The environment affects all diseases, usually because the pathogen requires specific temperature and moisture conditions in order to grow, develop, and infect the plant. But in this case it is the environment's effect on the plant that determines whether disease will occur. Corn plant susceptibility to stalk rots is greatly affected by environmental stress (Dodd, 1977).

Stress Effects on Stalk Rot Occurrence

The way in which stresses affect stalk rot can be summarized in terms of the photosynthesis of the plant (Dodd, 1977). During the grain-filling period, from pollination until physiological maturity, the carbohydrates produced in the plant by photosynthesis are in high demand by the developing kernels. When the growing conditions are less than ideal, the plant begins to experience some stress, which will reduce its rate of photosynthesis. The carbohydrates being produced are not adequate to meet the demands of the developing kernels, and so carbohydrates are translocated from the roots and stalk, making their cells more susceptible to fungal attack. Any stress that impacts the ability of the plant to conduct photosynthesis can enhance its susceptibility to stalk rot. These include drought stress, excess soil moisture (through depleted root health), leaf damage from hail or disease, insect injury to the roots or stalk, weed competition, prolonged cloudy weather, and nutrient deficiencies.

An interesting aspect of this idea is that plants with a higher number of kernels demand more carbohydrates for grain-fill, causing more stress on the roots and stalk. Several studies have indicated that in general, plants with higher kernel numbers are more likely to have stalk rot. So plants with a higher yield potential can be more vulnerable to stalk rot if growing conditions during grain-fill are not ideal. Higher kernel numbers can be the result of hybrid genetics (Koehler, 1960) or favorable early-season growing conditions (Dodd, 1980). Clearly, there is an advantage to having higher kernels numbers (more yield), but only if the late-season growing conditions are adequate to support filling a large number of kernels. Table 1 (from Dodd, 1981) indicates how the relationships among kernel number, stalk rot, and grain fill combine to affect total yield. In the first two examples, the plants set high numbers of kernels but died prematurely due to stalk rot, so that grain filling was incomplete and kernel weights and bu/acre were low. In the third example, plants with the same number of kernels did not die prematurely, so the kernel weights were higher and so was the yield per acre. Compared to the yield of the healthy plants, stalk rot caused a 31 to 55 bu yield loss. In the fourth example, the plants set fewer kernels and did not die prematurely, so kernel weights were high. Yield, however, was not maximized due to the lower kernel number.

Table 1. Relationships among kernel number, premature death due to stalk rot, kernel size, and total yield in the same corn hybrid (Dodd, 1981).

Premature death (days)	Mean kernel wt. (g)	Kernels/plant	Yield/plant (g)	Bu/A
22	0.25	640	160	151
13	0.29	640	186	175
0	0.34	640	218	206
0	0.34	550	187	176

Stalk rot development does not always follow this pattern. Under some conditions, *Colletotrichum graminicola* can be a more aggressive pathogen than the other stalk rot organisms, and its attack is sometimes unrelated to plant stress (Bergstrom and Nicholson, 1999). In these cases there is a systemic vascular wilt infection that is not characterized by the typical decay of the lower internodes.

For decades, researchers and agronomists have recognized a connection between European corn borer injury and stalk rot (Bergstrom and Nicholson, 1999; Chiang and Wilcoxson, 1961; Christensen and Schneider, 1950; Jarvis et al., 1984). Corn borers can influence stalk rot in three different ways: 1) they are vectors for stalk rot fungi; 2) they make entry wounds for airborne and splashed inoculum; and 3) they cause physiological stress that reduces photosynthesis. The contribution of corn borers to stalk rot development varies from year to year, depending on the corn borer population.

Conditions in 2000

Stresses differ from field to field, so the underlying causes of stalk rot are not the same in every field. This year, however, there was a common stress factor that contributed to stalk rot development in many fields, and that was inadequate soil moisture. An examination of soil moisture levels during the late season shows that there was a period of very low soil moisture between late August and mid-September for most of the state. Northeast Iowa did not experience this lack of soil moisture, and also did not experience the lodging problems common in the rest of the state. Fig. 1 shows the percentage of soils with inadequate soil moisture in the state as a whole. There was a sharp rise in the percentage of soils with short and very short topsoil moisture during the period between roughly Aug 28 and Sep 18. More than 70% of the soils in the state had less-than-adequate moisture by Sep 18. Subsoil moisture followed the same pattern, with an even greater moisture deficit than the topsoil. Much of the lodging took place during this period or just after it. The pattern was similar to the whole-state trend for each of the crop reporting districts in the southern 2/3 of the state. The lack of soil moisture was most pronounced in West-Central Iowa (Fig. 2). In Northeast Iowa, where lodging was not a problem, soil moisture was mostly adequate until very late in the season (Fig. 3).

Earlier in the season, low soil moisture also caused widespread drought-induced Potassium deficiency symptoms. Generally, Potassium deficiency is related to increased stalk rot susceptibility (Smith and White, 1988), but it is not clear whether this early-season phenomenon was related to stalk rot problems in 2000. Many fields with these Potassium deficiency symptoms later had severe stalk rot and lodging, but that may simply have been a correlation of both problems with low soil moisture.

High Nitrogen fertilization has been reported to promote stalk rot (Smith and White, 1988), and there are several examples in 2000 where higher levels of fertilizer or manure were associated with more severe stalk rot and lodging. When conditions are favorable for stalk rot, high Nitrogen fertility appears to have an effect on stalk rot. But there are many examples in which Nitrogen levels have no effect on stalk rot. There is a complex interaction between stalk rot, soil fertility, environmental conditions and plant genetics, so it is difficult to generalize about the effects of fertility or fertilization on stalk rot.

Some plants lodged without any evidence of stalk rot at the point of breakage. In some cases, the plants had stalk rot at the stalk base, and this caused the stalk tissue to dry out rapidly, so that the pith tissue separated from the rind. In other cases, it appeared that there was no stalk rot, but the dry soil conditions combined with high temperature and wind caused a similar drying of the stalk tissue, even without stalk decay. When the pith separates from the stalk rind, the stalk is very weak and vulnerable to lodging.

European corn borer injury did not seem to be an important factor in stalk rot this year.

Finally, there were fields with extensive root lodging as well as stalk lodging. Root lodging is not related to stalk rot, although some of the fields I observed had high levels of both root lodging and stalk rot. Root lodging seemed to be a result of poor root development combined with high winds. The role of wind in lodging should not be underestimated. In many cases, differences in lodging from field to field or within fields are simply due to the random nature of wind gusts.

Outlook for Next Year

Occurrence of stalk rots from year to year is not predictable, although fields where corn follows corn are at a higher risk for stalk rot and other diseases. Recommendations for stalk rot management for next year are no different than the usual recommendations. Tillage does not reduce stalk rot incidence or severity. Losses can be reduced by scouting fields 40-60 days after pollination and looking for symptoms or pinching stalks. If more than 10-15% of stalks are rotted, the field should be scheduled for the earliest possible harvest. Even if the corn must be harvested at a higher moisture content, it will pay to harvest before extensive lodging takes place. Severe stalk rot can be avoided by reducing the stresses that predispose plants. It is not possible to completely control stalk rots; however, following are several procedures that should aid in control.

Hybrid Selection

All hybrids will suffer stalk rot under some conditions. Hybrids vary in their tendency to suffer stalk rot, but specific genetic resistance is difficult to define. Stalk rot resistance is often related to the plant's ability to tolerate stress and maintain high carbohydrate production, in addition to partial genetic resistance to the pathogens. Where soil moisture is consistently low, a more drought-tolerant hybrid will be less vulnerable to stalk rot. Hybrids that have good standability are those that do not lodge easily; they may have partial resistance to stalk rot infection or other characteristics that make them less vulnerable to lodging. Hybrids that are more resistant to leaf diseases will avoid leaf blight stress that increases stalk rot susceptibility. Hybrids that appear very susceptible in one year may not be particularly susceptible in other years, because of the interactions among hybrid genetics, environment, and stalk rot fungi.

Plant population

Plant the population recommended for the hybrid and consider the site conditions. High populations result in plant competition for light and water, resulting in reduced photosynthesis and greater stalk rot susceptibility. In dense stands, plants tend to elongate and have weak, spindly stalks. Such plants succumb more easily to stalk rot and lodge quite readily. An appropriate plant population in one year may be too high in another year.

Insect and Weed Control

Damage from stalk-boring insects, particularly the European corn borer, contributes greatly to stalk rot development. Root-feeding insects such as corn rootworms also may contribute to stalk rot infection. Controlling these insects will reduce stalk rot damage in some years. Heavy weed pressure contributes to stress on the plants, predisposing them to stalk rot development. Therefore, weed control can sometimes help reduce stalk rot damage.

Timely Harvest
Delaying harvest of affected fields beyond safe grain moisture levels increases the risk of losses due to lodging. Early maturing hybrids sometime suffer greater losses to stalk rots because they are not harvested in a timely manner.

Water Management
Improving drainage will prevent saturated conditions that can lead to a root and stalk rot problem. Where rainfall is inadequate and irrigation is used, it is important to maintain adequate moisture throughout the grain filling period.

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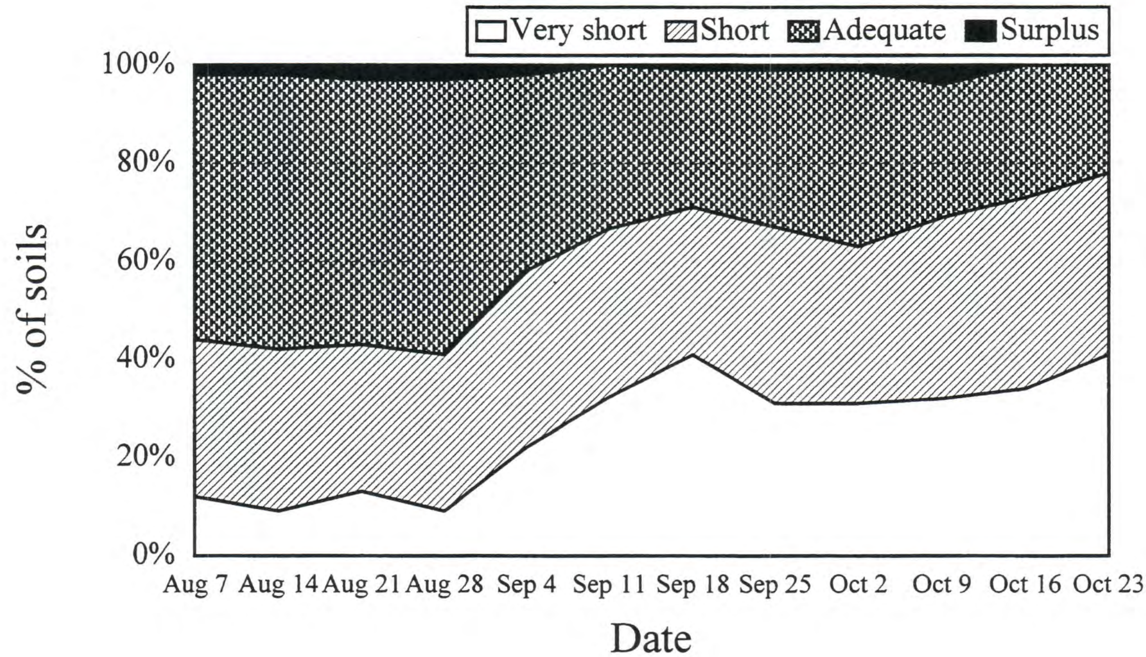

Fig. 1. Topsoil moisture in Iowa for Aug 7 to Oct 23, 2000

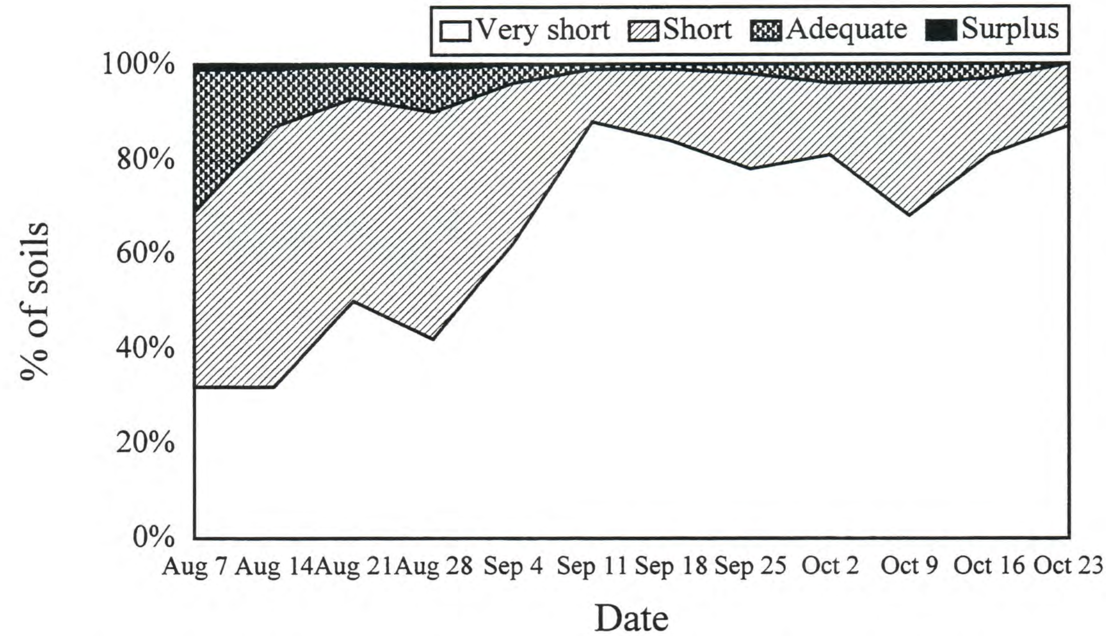

Fig. 2. Topsoil moisture in West-Central Iowa for Aug 7 to Oct 23, 2000

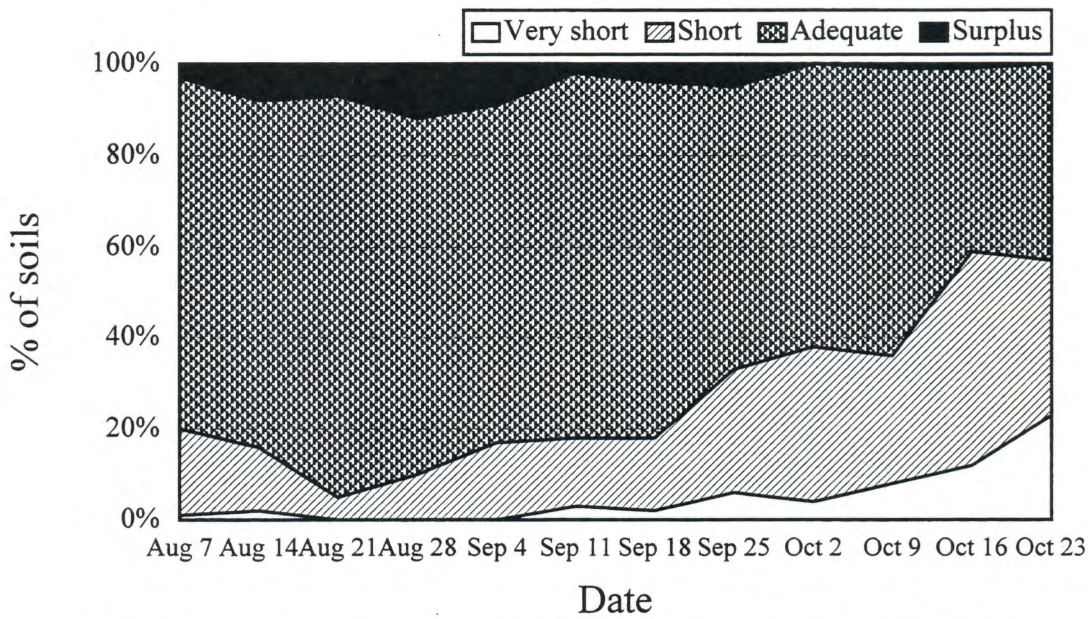

Fig. 3. Topsoil moisture in NE Iowa for Aug 7 to Oct 23, 2000